GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: April 22, 1980

Project Title: Role of Fluid Mechanics in the Genesis, Proliferation and Detection of Atherosclerosis

Project No: E-16-664

Project Director: Don P. Giddens

Sponsor: National Science Foundation; Washington, D. C.

Agreement Period: From February 15, 1980 Until ~~July 31, 1981*~~ 7/31/82 8/31/82
(Grant Period includes 6 month unfunded flexibility period)

Type Agreement: Grant No. CME-7921551

Amount:

$121,350	NSF*
55,000	GIT (E-16-343)
$176,350	TOTAL

Reports Required: Progress Report containing request for continued support; Final Report

Sponsor Contact Person (s):

Technical Matters	Contractual Matters (thru OCA)
George K. Lea National Science Foundation Washington, D. C. 20550 (202) 632-5787	Karen Sandberg National Science Foundation Washington, D. C. 20550 (202) 632-5892

*This is a continuing grant which has been approved for approximately 3 yrs. Continge on availability of funds and scientific progress, NSF expects to continue support at $115,838 for Year Two and $122,790 for Year Three.

Defense Priority Rating: None

Assigned to: Aerospace Engineering (School/~~laboratory~~)

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E-16-724

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 10/27/83

Project No. E-16-664 ✓ School/~~Dept~~ Aerospace Engr.

Includes Subproject No.(s) E-23-653 ✓

Project Director(s) D.P. Giddens GTRI/~~GIT~~

Sponsor National Science Foundation

Title: Role of Fluid Mechanics in the Genesis, Proliferation and Detection of Atherosclerosis

Effective Completion Date: 8/31/83 (Performance) 8/31/83 (Reports)

Grant/Contract Closeout Actions Remaining:

- [x] None
- [ ] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other _____

Continues Project No. _____

Continued by Project No. E-16-645

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Form OCA 58:1004

E16-664

PROGRESS REPORT

GRANT NO: CME-7921551

TITLE: ROLE OF FLUID MECHANICS IN THE GENESIS, PROLIFERATION AND DETECTION OF ATHEROSCLEROSIS

PRINCIPAL INVESTIGATOR: DON P. GIDDENS

PERIOD COVERED: FEBRUARY 15, 1980 TO DECEMBER 31, 1980

This Report will deal with progress in two areas: Stenotic Flow Studies and Carotid Artery Fluid Dynamics. These were areas in which we proposed work during the first year of the three year grant period.

I. STENOTIC FLOWS

A. Basic In Vitro Studies

A two-component Laser Doppler Anemometer system has been set up for velocity measurement in stenotic flow fields. A large flow system has been completed for steady and pulsatile flow. A model stenosis has been cast from plexiglas and installed in the facility. Initial experiments on steady flow over a physiologically relevant range of Reynolds number have been almost completed as a precursor to pulsatile flow studies which model the monkey aorta. One Ph.D. student, Mr. Saad Ahmed, has presented a Thesis Proposal to the Aerospace Engineering Faculty and is presently working on his dissertation in this area.

B. In Vivo Studies with Coarctations in the Monkey Aorta

In collaboration with Drs. Seymour Glagov and Christopher Zarius, two series of animal studies have begun. In July 1980 a group of four monkeys were operated on by the University of Chicago group and severe coarctations were installed in the descending aorta. Investigators from Georgia Tech performed hemodynamic measurements at the time of surgery. All of these animals survived and have been fed an atherogenic diet for the past six months. They will be sacrificed in mid-January. At this time additional hemodynamic studies will be performed to characterize the aortic flow conditions, pre- and post-stenotically. After sacrifice, pathology studies will be performed at the University of Chicago. Specific models of one or more of these monkey aortas will be made for in vitro fluid dynamic experiments at Georgia Tech.

A second series of five monkeys was begun in October 1980. These animals were fitted with mild coarctations which produced very little pressure gradient but gave a turbulent poststenotic flow. These animals are all presently on the atherogenic diet and will be sacrificed in April, 1981.

II. CAROTID ARTERY FLUID DYNAMICS

A. Fluid Dynamic Measurements in Average Model

Under previous NSF funding an "average" model of the human carotid bifurcation was developed and steady flow experiments with flow visualization and laser Doppler

anemometry were begun. These experiments are now completed and several papers have been presented along with the preparation of several manuscripts. Recently, the flow facility has been modified for pulsatile flow, and early flow visualization studies are now in progress.

B. In Vivo Measurements in Humans

In July 1980 Dr. Max Casty from Zurich, Switzerland joined our group as a Visiting Research Scholar. Dr. Casty brought with him a multichannel pulsed Doppler ultrasound instrument developed in Zurich. We have been using this device to study carotid artery hemodynamics noninvasively in normal subjects and in patients at Piedmont Hospital in Atlanta. We are modifying the instrument, which is microprocessor-controlled, to allow for one of the 26 channels to be employed for turbulence detection. These studies should provide new knowledge of human carotid hemodynamics which we hope to apply to both the genesis and detection aspects of atherosclerosis.

C. Pathology of Carotid Arteries

The group at the University of Chicago is harvesting human carotid arteries for pathologic studies to parallel the hemodynamic measurements. This phase of the work has only recently begun.

PAPERS PRESENTED ARISING FROM GRANT

1. "Steady Flow at the Carotid Bifurcation", 2nd Mid-Atlantic Conference on Biofluid Mechanics, Blacksburg, VA., May, 1980. K. Balasubramanian, D.P. Giddens, and R.F. Mabon.

2. "Flow in the Carotid Bifurcation", presented at a Specialists Meeting on Hemodynamics and the Arterial Wall, Houston, Texas, November, 1980. K. Balasubramanian, R.F. Mabon, and D.P. Giddens.

3. "Flow Studies at the Carotid Bifurcation", ASME 1980 Centennial Winter Annual Meeting, Chicago, 1980. K. Balasubramanian and D.P. Giddens.

PAPERS PUBLISHED

1. K. Balasubramanian, D.P. Giddens, and R.F. Mabon; "Steady Flow at the Carotid Bifurcation", Biofluid Mechanics Vol. 2, ed. by Schneck, Plenum Press, pp. 475–496.

MANUSCRIPTS PREPARED

1. K. Balasubramanian, R.F. Mabon and D.P. Giddens; "Investigation of Steady Flow in a Model of the Human Carotid Bifurcation by Flow Visualization". Submitted to Journal of Biomechanics (under review).

2. K. Balasubramanian, R.F. Mabon and D.P. Giddens; Investigation of Steady Flow in a Model of the Human Carotid Bifurcation by Laser Doppler Anemometry". Submitted to Journal of Biomechanics (under review).

PROFESSIONAL PERSONNEL WHO WORKED ON GRANT

1. D.P. Giddens, Ph.D. - Principal Investigator

2. R.F. Mabon, M.D. - Co-Principal Investigator

3. Max Casty, M.D., Ph.D. - Visiting Research Scholar

4. K. Balasubramanian, Ph.D. - Postdoctoral Fellow

5. Christopher K. Zarins, M.D. - Co-Principal Investigator on Subcontract with University of Chicago

6. Seymour Glagov, M.D. - Co-Principal Investigator on Subcontract with University of Chicago

SUMMARY OF SCIENTIFIC PROGRESS (E-16-664)

The following research results have been achieved under this grant.

1. Stenotic Flow Field Studies. An extensive series of experiments involving flow field measurements with laser Doppler anemomnetry has been completed. A Ph.D. thesis resulted from this work, and we are now in the process of preparing manuscripts for submission to technical journals. Subsequently, the results will be employed to aid in the interpretation of our in vivo experiments in monkey aortas.

2. Monkey Coarctation Studies. Fluid dynamic and pathology measurements relating to the development of atherosclerosis in monkey aortas have been completed for two series of monkeys (eleven animals total). These data are still under analysis, but two papers have been presented during the past year to report preliminary findings and a manuscript is now being written. An important result is that regions of high wall shear stress and/or turbulence are consistently spared of atherosclerotic lesions. A new series of animals is presently under study in which a femoral artery/vein shunt is created in one leg to develop high shear rates while the other leg is not modified. This series is designed to separate effects of high laminar shear stress and turbulence.

3. Carotid Artery Studies. Steady flow field measurements in the "Georgia Tech" model carotid artery have been completed and analyzed. Human carotid arteries have been harvested by the University of Chicago group, and the detailed distribution of atherosclerotic lesions has been described. It has been found that a significant correlation exists between plaque development and low wall shear stress arising from flow separation while high wall shear stresses are significantly associated with sparing by lesions. Those studies are continuing into additional harvesting and pathologic description of human carotids and into a detailed fluid dynamic

study of pulsatile flow in the carotid model. Preliminary pulsatile flow visualization has been completed and reported in a paper. The correlation between disease development and the flow field has been reported in two recent papers.

4. Quantitative Flow Visualization. The projection equipment has been set up to study particle tracing in a flow using computer imaging techniques, and an initial program has been developed. We plan to study particle paths and residence times in the carotid model using this approach.

Paper Presentations:

1. D. P. Giddens, C. K. Zarins, S. Glagov, R. F. Mabon and D. N. Ku; "Acute and Chronic Flow Disturbances Due to Aortic Coarctation in Monkeys", Vascular Research Forum, Annual Meeting of the Society of Vascular Surgery and International Cardiovascular Society, Dallas, TX, June 1981.

2. D. P. Giddens, C. K. Zarins, S. Glagov, R. F. Mabon, D. N. Ku and M. Casty; "Flow Disturbances and Atherogenesis in the Monkey Aorta", 34th ACEMB, Houston, TX, Sept. 1981 (invited).

3. D. N. Ku and D. P. Giddens; "Pulsatile Flow Visualization in a Carotid Bifurcation Model", 34th ACEMB, Houston, TX, Sept. 1981.

4. D. P. Giddens, C. K. Zarins, B. K. Bharadvaj, R. F. Mabon and S. Glagov; "Fluid Dynamics and Plaque Localization in the Carotid Bifurcation", 1981 ASME-WAM, Washington, Nov. 1981.

5. C. K. Zarins, D. P. Giddens, K. Balasubramarian, V. Sottiurai, R. F. Mabon and S. Glagov, "Carotid Plaques Localize in Regions of Low Flow Velocity and Shear Stress", 54th Scientific Sessions, American Heart Association, Dallas, TX, Nov. 1981

Ph.D. Thesis

Saad Ahmed; "An Experimental Investigation of Steady and Pulsatile Flow Through a Constricted Tube", Ph.D. Thesis, Georgia Institute of Technology 1981.